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Harnessing Wind Comfort in Coastal Resort Malaysia

Wan Mohd Taufiq Wan Jabarudin* and Zarina Yasmin Hanur Harith

Building Department, Faculty of Architecture, Planning and Survey, UniversitiTeknologi MARA, Shah Alam, Malaysia

Abstract

Air conditional system consumes high energy and the most of coastal resort owners install this system to avoid thermal discomfort due to the lack of sufficient wind speed in the closed area. The wind flow around the structure does affect the air change rate within the building and to promote energy saving campaign for better future, the wind originated from the sea utilization need to be maximize and replace the air-conditional system. The evaluation of wind mapping will represent the wind flow and the relation of the building density in selected case study areas.

Keywords: Wind comfort; air performance; wind tunnel; coastal resorts; human comfort

1. Introduction

The development in the industrial, agricultural, commercial and housing sectors have caused electricity consumption in Malaysia rapidly increasing. Other reasons for the rise in electricity consumption include the increased population growth and the improved life style. The electricity consumption per household depends very much on family size, living habits, number and age of electrical appliances and their hour of usage (Taha, 2003).

Each of electrical appliances is differ with each other in energy usage and even frequency of usage. The average energy used by various appliances and their daily costs are given in Fig.1and Fig. 2 (Taha, 2003). From the Fig. 1, the air-conditioner use 14% of daily energy for the domestic sector usage which

* Corresponding author. Tel.: +0-012-3084747;
E-mail address: ripperwonderland@gmail.com.

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is at the second place after the fridge. In order to maintain a temperature a few degrees above the freezing point of water throughout the day, the fridge will be working 24 hours a day. However, compare to the air-conditioner, the hour of usage is less than fridge but still as a major energy usage in our homes. The air-conditioner use 14% of daily energy for the domestic sector usage. Despite the high energy usage, air-conditioner is consuming more money per day than other electrical appliances. It is been shown on thefigure 2 where the air-conditioner is figuratively cost more than others. From these two charts, it showed us that air-conditioner not only consume more energy but also cost more in your domestic electrical bill.

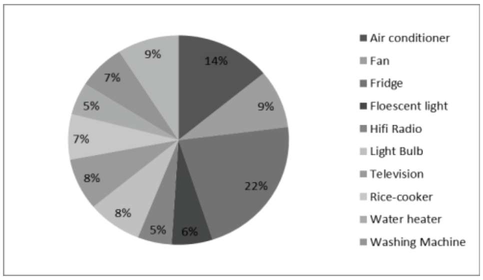

Fig.1. Energy uses in residential sector

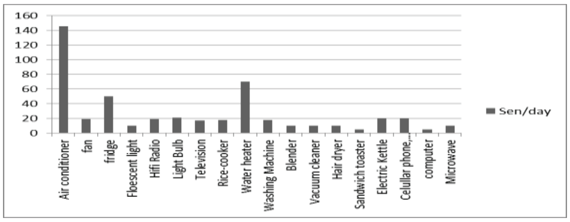

Fig.2. Estimated daily electricity cost per day of various domestic appliances; Source: Taha, (2003)/ JabatanBekalanElektrikdan Gas Malaysia (2003)

2. Research Background

Wind conditions will affect the ventilation of buildings as well as the comfort and safety of occupants. And it also important in the dispersion of traffic related pollutants and diffusion of heat. Therefore, it is necessary to understand the pedestrian wind environment around buildings for taking them into account in the major design. (Kubota T., Miura, Tominaga, & Mochida,2008). The best practice to reduce the usage of air condition and electrical bills is by improving the natural ventilation. The flow of wind from the sea is infinity but it is never been fully utilized as today beach resort prefer a closed chalet and ventilated with air-conditional system. As the outdoor air enters and leaves a house either by: infiltration, natural ventilation, and mechanical ventilation will improve the air exchange rate. (Stathopoulos, 2009)

The Air exchange rate is defined as the number of times the air within the space is replaced. To calculate the air exchange rate, the air change per hour (ACH) equation is used, which is: (Bearg, 1993)

$$N = \frac{60Q}{Vol.} \tag{1}$$

Where: *N = number or changes per hour*

Q = Volumetric flow rate of air in cubic feet per minute (cfm)

Vol = Space volume L x W x H in cubic feet

From the equation, the volumetric rate of air in cubic feet per minute is the total flow rate of air into the area and Q can be determined using:

$$Q = \vec{V}A, \tag{2}$$

Where: $\vec{V}$ *= average velocity in SFPM (standard feet per minute),*

A = cross-sectional area of duct or pipe (opening) (in ft2)

From here, the velocity of wind into the duct or pipe (between outdoor and indoor or called opening in this situation) will determine the rate of air exchange into the area. This show the higher velocity of wind around the building will increase the air exchange rate of the building. Therefore the velocity around the wind must be identified.

One of the ways to identify the wind condition is the wind tunnel. The low-velocity wind tunnel is the test to identify the characteristic of the wind experienced by the building or structure. The wind induced response is dynamic as the wind velocity, wind pressure and various shapes of building (either aerodynamic or not) as the causes (Stathopoulos, 2009)The wind tunnel prompted used on the concern of structural integrity, wind induced or horizontal acceleration to building (related to occupant comfort) and the effect of wind on pedestrian as well as the environment (related to dispersion of heat and pollutant), (Jack, Isyumov, & Committe, 1998).

Then, the CFD method can be used to determine the result as the CFD works similar to the wind tunnel test.The use of CFD for investigating the pedestrian wind environment around building is recommended by COST (European Cooperation in the field of Scientific and Technical Research) group. (Tominaga, et al., 2008).

Humphreys has developed a rule which uses a monthly mean external temperature to determine an optimum temperature which is called Thermal Neutrality.(Humphreys, 1978)Thermal neutrality is at the condition where the occupant is comfortable with the surrounding as they feel neither too cold nor too hot. At the temperature where thermal neutrality is felt is called effective temperature.

In controlling the effective temperature, the relative humidity, air flow and mean temperature will affect the value of effective temperature. The relative humidity will increase the effective apparent temperature while air flow will reduce the effective temperature. Higher mean temperature will lower the offset temperature require to acquire thermal neutrality (Harriman, 2008).

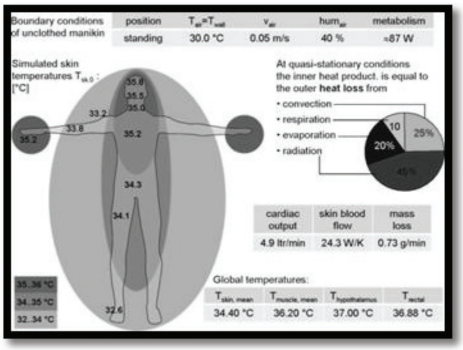

Fig.3. Thermal Neutrality for Human Body; Source from http://www.theseus-fe.com/thermal-manikin/thermal-maikin-neutrality.html.

2.1. Climatic condition in Malaysia

Malaysia it is water surrounded country that located roughly between ° 30' North latitude and 112° 30' East longitude. Geographically, Malaysia can be divided into a Peninsular West Malaysia and an Island East Malaysia. West Malaysia consists of peninsular Malaysia which can further be divided into east peninsular Malaysia and west peninsular Malaysia. It is bordered by Thailand in the north; the South China Sea on the east side, while the Straits of Malacca on the west coast separates the peninsula from Sumatra and Straits of Johor from Singapore. East Malaysia is located on the north and northwest side of the island of Borneo with Sabah occupied in the northern half and Sarawak situated in the west. East Malaysia is bordered by the South China Sea along its northwest coast, by the Sulu Sea and Celebes Sea at the northeast section of Sabah, while on the south side; it has a common boundary with Kalimantan (Indonesia).

The ocean based activities source is the major contributor to the gross domestic product for Malaysia. The Malaysian coastal region supports a large number of people who live along its 4675 km of coastline. The importance of its coasts for economic activity has only increased in recent years as ports for trade, infrastructure for tourism and recreational activity, and industries have started taking up a larger portion of the coastal landscape. Aside of fishery and other aquaculture activities, seaside tourism is proven to be the most profitable coastal industry. The Malaysia's marine assets have always been major attraction for tourists to the country.

3. Outlines of Case Study Area

3.1.1. The Case Study:Terrengganu

Terengganu is located in the east coast part of the Peninsula Malaysia. It's well-known for its beautiful islands and beaches. The case study is located at Kg RhuTapai, Merang which is about 34km from Kuala Terengganu and 446km from Kuala Lumpur. The selection of the area was based on distance of the resort from sea and recommendation from tourism agency. The location for the study is a seaside resort that around 15m from the beach and facing ocean. The maximum height for the building in the area is 2 storeys or 15m height.

Fig. 4. Sutra Beach Resort

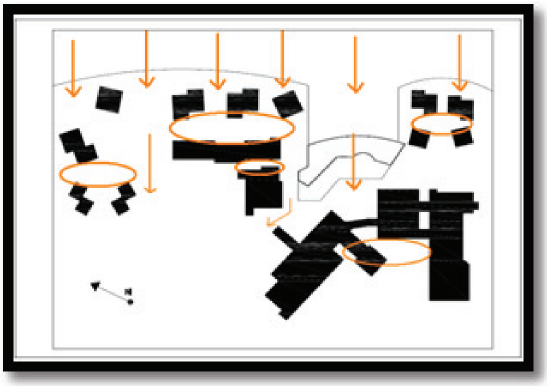

Fig. 5. Layout of the case study and example of wind flow in the area

3.1.2. Calculating gross building coverage ratio

Both building coverage ratio (BCR) and floor area ratio (FAR) are used to estimate the building density of a site area from two aspects, the buildings stretching on the surface and growing along the third dimension. A BCR is the ratio of the total standing area of all buildings to the total area of the interest area, while a FAR is the ratio of the gross floor area of all buildings to the total area of the interest area

After obtaining the building's height, the BCR and the FAR within an area of interest are calculated from the following equations: (Xian-Zhang, Qi Guo, Chen, Liang, & Sun, 2008)

$$BCR = \sum F / A \tag{3}$$

$$FAR = \sum (H / C \times F) / A \tag{4}$$

Where H is the height of a buildings, F is a building's standing area, C is a constant which represents the average height of one storey of all the buildings (here C = 3.6 m), A is the total area of a site, FAR and BCR is the floor area ratio and building coverage ratio of a site.

Table 1. Brief outline of case study areas for wind tunnel tests

Case	Gross Building coverage ratio (%)	Gross floor ratio (%)	Ratio of buildings coverage of each stories (%)	
			1-2	more than 2
1	10.49	16.45	100	-

4. Research Methodology

Research can be described as a new finding that based on previous research. The way on how to conduct the research was done on research methodology or research design. Thus, the methodology of this research is following the sequential steps and procedures described below:

Table2. Research methodology

Step	Progress
Step 1:	To Survey the types designs and sizes of the structure within the area to be studied
Step 2	To gather all climatic data and meteorological references on the site using the anemometer or data given by Meteorological Department.
Step 3:	Rescale the area into 1:300 to fit into the wind tunnel's test section
Step 4:	To assemble the scaled model.
Step 5:	Gather the data on mean wind velocity on each 50 receiver on the model
Step 6:	Run the CFD test based on the Wind Tunnel model captured by high speed Camera
Step 7:	Compare the results from wind tunnel and CFD
Step 8:	A evaluation on the data based on the previous researchers (Kubotaa, Miurab, & Tominagac, 2003)

4.1. Scope of Design

4.1.1. Equipment :Wind tunnel experiments

The close wind tunnel at International Islamic University Malaysia was used for the tests (

Fig.). The cross-section of the wind tunnel is 1.5m x 2.5m, with a test length of 6m. The vertical profile of mean wind velocity in the tests was prepared to obey the maximum wind velocity can be tested is 40 m/s-2.

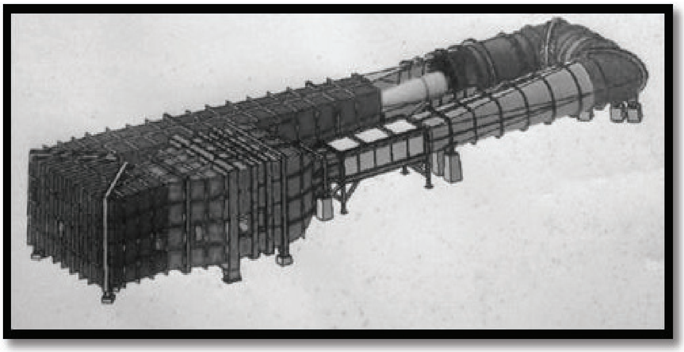

Fig.6. The Closed Circuit Subsonic Wind Tunnel

4.2. Method: Particle image Visualization

The models for the tests are scaled in 1/300. Since the main purpose of the present study is to assess the effects of building patterns on the wind flow, the models did not take into account the existing trees, setbacks and roof shape of buildings. The physical measurement is carried on the PIV-Particle Image Visualization.

P.I.V is an optical method of to obtain velocity measurements and related properties in fluids. The fluid is seeded with tracer particles which, for sufficiently small particles, are assumed to faithfully follow the flow dynamics and vectors in the fluid. (Kubota & Ahmad, 2006)

The motion of the seeding particles is used to calculate speed and direction (the velocity field) of the flow can be studied. The fluid is illuminated by laser and captured by high speed camera so that particles are visible. The model used for the test must be in pitch black colour to reduce the amount of light reflection in the test section which can disturb the data collection.

During the test, a roughness element must be placed to create the roughness boundary elements that created by wind obstacles like land elevation, vegetation and static human-made structures. By referring to Table 3, the roughness of the area which is on Smooth where the area is low dense in vegetation and within 10m contour from the sea level. The roughness element will be placed at in front of the model as an obstacle before wind reaches the model.

Table 3. Roughness Classification After Davenport Et Al. (2000) (Davenport, Grimmond, Oke, & Wiering, 2000) With Power Law A Values After Asce 1999 (American Society Of Civil Engineers Asce, 1999)

Roughness Class	Z_0(m)	α	G (m)
Sea	0.0002	0.09	213
Smooth	0.005	0.125	213
OC	0.03	0.15	274
Roughly open	0.1	0.2	274
Suburban (rough)	0.25	0.25	366
Very Rough	0.5	0.3	366
Urban (Closed)	1	0.33	366

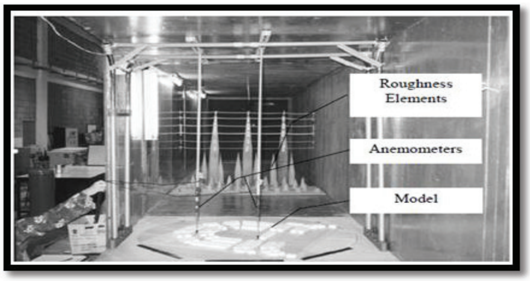

Fig.7. Arrangement of model before test conducted (Source from “Wind Environment Evaluation In Neighborhood Residential Areas In Malaysia” Tetsu Kubota and Supian Ahmad 2004)(Kubota & Ahmad, Wind Environment in Neighboorhood residential areas in Malaysia; A case study of Johor Bharu Metropolitan City, 2004)

5. Method of Evaluation

5.1. Evaluation through the comfort zones of daily mean wind velocity and building Density

The wind environment evaluation was carried out based on the results of the wind tunnel tests. The wind velocity ratios, which measured in the wind tunnel tests, were transformed from the actual wind velocities by using the climate data of Kuala Terengganu Station and the wind environment of the selected case study areas were evaluated under the same climate conditions by using the existing criteria for wind environment.

The actual wind velocities at 1.5m height in all measuring points were calculated by using the above climate data of Kuala Terengganu station. It indicates that the mean wind velocities of each case study areas under the climate conditions of Kuala Terengganu station as the y-value. (Kubota, Miura, Tominaga, & Mochida, 2003)In the search of comfort zones of daily mean wind velocity, Murakami has suggested that taking account of the daily mean temperature. According to Murakami, wind velocity range of 0.7-1.7m/s is the suitable zone for wind environment under the daily mean temperature of 25°C or more. (Murakami & Morikawa, 1985)(Appendix A)

5.2. Evaluation through the thermal neutrality

According to Aynsley, Survey of human thermal response in South East Asia produce the following equation for estimating thermal neutrality Tn base on the mean monthly dry bulb temperature Tm: (Aynsley, 1999)

$$T_n = 17.6 + (0.31\, x T_m) \quad (5)$$

Where: T_n = thermal neutrality

T_m = Mean of external dry bulb temperature. For 90% acceptability for thermal comfort suggested is Tn ± 2.5 K and 80% acceptable for comfort suggested Tn ± 3.5 K. The average dry bulb temperature for Kuala Lumpur from 2000 to 2010 is 28°C, thus the thermal neutrality will be:

$$\begin{aligned} T_n &= 17.6 + (0.31\ x\ T_m) \\ &= 17.6 + (0.31\ x\ 28) \\ &= 26.28\ °C \end{aligned} \quad (6)$$

Comfort zone for 90% acceptable, then temperature must not be more than

$$26.28\ °C + 2.50°C\ =\ 28.78°C \quad (7)$$

For 80% acceptability, minimum temperature range for comfort will be:

$$26.28\ °C + 3.50°C\ =\ 29.78°C \quad (8)$$

The air flow to offset the excess temperature is given by:

$$V = (excess\ temperature/3.67) + 0.2\ m/s \quad (9)$$

Let say, the excess temperature is 2.1°C, then the air flow required = 0.7 m/s for the upper limit. To compensate for the temperature of thermal neutrality, the air flow required is 1.5 m/s. ((Zain, Taib, & Baki, 2007)

6. Expected result

The result that will be expected from this research is the critical critics on the conventional design that been used by the beach resort owner for the better design which fully utilize the air flow as natural ventilation. From the comfort velocity evaluation will determine the better wind mapping especially in building position and building cluster density. The flow and velocity of the wind will be showed in this evaluation. Then the thermal neutrality evaluation will determine the velocity of wind needed in to keep effective temperature in each building in the area. (Pendwarden & Wise, 1975)

With both evaluation compiled will create a practical design for full natural wind ventilated buildings in coastal resort or any building in the coastal area.

7. Conclusion

The wind performance is one of the main parameter in the total building performance system. It also related to the thermal comfort as the air velocity is one of thermal comfort variable. In the developed countries, a wind performance through “beoufort scale” has been developed to determine the velocity of wind flow around the building.

As tropical country, the wind velocity in Malaysia is practically low and it’s impossible to generate energy using wind turbine. However the wind still needed to disperse the excessive humidity and keep a fresh air flow in the building. (Stathopoulos, 2007)

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Appendix A. Criteria for assessing wind-induced discomfort cons idering temperature effect (Murakami and Morikawa, 1985)

Murakami and Morikawa (1985) proposed the wind velocity ranges to avoid thermal discomfort during the summer months due to insufficient wind speed as well as the problems caused by the strong wind in and around buildings. In their proposal, both upper and lower limits of wind velocity are changed according to the increase of the daily mean temperature. The proposed criteria are indicated in **Error! Reference source not found.**.

The criteria represent comfort and discomfort of human subjects induced by the wind in and around buildings.

A.1. Criteria for Assessing Wind-Induced Discomfort Considering Temperature Effect; Source: Murakami and Morikawa, (1985)

(at 1.5m height)	Daily mean temperature (°C)		
	<10	10-25	>25
Daily mean wind velocity that result in weak wind-induced discomfort	-	-	0.7m/s
Daily mean wind velocity that is transferred from comfort range to strong wind-induced discomfort ranged	1.3m/s	1.5m/s	1.7m/s

Daily mean wind velocity that begins to result in strong wind-induced discomfort	2.0 m/s	2.3m/s	2.9m/s

Appendix B.

The methods used in the calculations were used by Kubota and Ahmad (2006) to calculate actual wind velocities . Firstly, we assumed that the vertical profile of mean wind velocity in the respective case study towns corresponded with a 1/4 power law. Then, the wind velocities in a wind tunnel at the height of respective weather stations (U_h) were calculated by:

$$U_h / U_\infty = (Z_h / Z_\infty)1/4 \tag{1}$$

Where is the wind velocity in a wind tunnel at the height of respective weather stations (m/s); U_∞ is the reference wind velocity above boundary layer in a wind tunnel (m/s); *zh* is the height in a wind tunnel, which corresponds with that of the weather station (mm); Z_∞ is the reference height above boundary layer in a wind tunnel (mm). Secondly, the actual wind velocities in each measuring point in the respective case study towns at1.5m height ($V_{1.5}$) were calculated by:

$$V_{1.5} / V_h = U_{1.5} / U_h \tag{2}$$

Where $V_{1.5}$ is the actual wind veloci ty in the respective case study towns at 1.5m height (m/s); V_h is the mean wind velocity based on the climatic data (m/s); $U_{1.5}$ is the mean wind velocity measured by the wind tunnel tests (m/s). The above calculations were made at all measuring points in every 16 wind directions. And then, the mean wind velocities in the respective measuring points were calculated in consideration of wind roses. The verification of the methods have been made in the previous researchers (Kubota T. , Miura, Tominaga, & Mochida, 2002)